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October 26, 2007

**To:** Environmental Protection Agency  
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**Attention:** Mr. David Boris  
Contract Officer

**From:** Kevin Whitney  
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**Subject:** Work Plan for Amendment 1 of Work Assignment 0-01, EPA Contract EP-C-07-028, under SwRI Project 03.13363, SwRI Proposal No. 03-50782.

Contract Title: "Testing and Related Support for Energy Bill-Mandated Activities"

Assignment Title: "Comprehensive Gasoline Light Duty Exhaust Fuel Effects Test Program to Cover Multiple Fuel Properties and Two Ambient Test Temperatures"

## 1.0 INTRODUCTION

Section 1506 of the Energy Policy Act of 2005 (Energy Act) requires EPA to produce an updated fuel effects model representing the 2007 light duty gasoline fleet, including determination of the emissions impacts of increased renewable fuel use.

The use of ethanol in gasoline has increased more than five-fold since 2000, and it is likely that its use will continue to expand into the next decade. It is also likely that use of high-level blends such as E85 will expand significantly.

Additionally, recent investigation related to the Mobile Source Air Toxics (MSAT2) rulemaking has shown that hydrocarbon emissions from light duty gasoline vehicles increase significantly as test temperature is decreased. As a result, the MSAT2 rulemaking promulgated NMHC standards at 20°F. However, this being a relatively new area of study, fuel effects data at temperatures lower than 75°F is scarce for use in emissions models.



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Hydrocarbon (HC) emissions are composed of hundreds of compounds, some of which have been identified by the EPA as air toxics. The Clean Air Act directs EPA to set standards to reduce air toxics emissions. Most existing data on the fractional relationship between the various air toxics and HC emissions has been established using vehicles meeting Tier 0 emissions standards (now more than 10 years old), and burning fuels that did not contain ethanol.

In order to help EPA develop a better understanding of the impact of ethanol fuel blends on light duty vehicle emissions, Southwest Research Institute® (SwRI®) will conduct Work Assignment 0-01, "Comprehensive Gasoline Light Duty Exhaust Fuel Effects Test Program to Cover Multiple Fuel Properties and Two Ambient Test Temperatures". SwRI will comply with the requirements of Work Assignment 0-01 as described in the EPA Statement of Work (included in Appendix A), with reservations and exceptions as noted below in Section 8.

## **2.0 TECHNICAL DISCUSSION**

The objective of Work Assignment (WA) 0-01 is to fill significant data gaps on fuel effects for the newest-technology (Tier 2) vehicles follows:

- Multiple levels of ethanol in gasoline will be examined in this test program, along with ethanol's interactions with other fuel properties such as volatility and distillation parameters.
- Varying levels of aromatics will also be evaluated, as they continue to be of interest due to their relationship to emissions of air toxics and the formation of particulate matter in the atmosphere.
- A portion of the tests will be performed at 50°F to fill the gap in the existing data at reduced ambient temperatures.
- This program will generate speciated VOC data from current model Tier 2 vehicles while operated on all test fuels. VOC compounds of interest include C<sub>1</sub> – C<sub>12</sub> hydrocarbons as well as light alcohols, aldehydes, and ketones. These measurements will be in addition to the standard measurement of total hydrocarbons with a flame ionization detector.
- PM mass will be measured for each test.
- An option is included for conducting limited PM speciation and measurement of non-VOC emissions for a subset of tests is included.

## **3.0 SCOPE OF WORK**

This work assignment requires that SwRI procure 19 suitable test vehicles with certain specifications (as detailed below). EPA has requested options for testing these vehicles using two different fuel matrices. Option A is for 17 fuels and Option B is for 23 fuels. The test fuels will be procured by SwRI. Each of these options includes different levels of effort for determination of VOC emissions and optional non-VOC emissions. The number of fuels will determine the required number of tests, which will have a substantial impact on the schedule and cost of the program. Additionally, there are two options for randomizing the test matrix. With Option C duplicate tests

on a specific vehicle/fuel combination are conducted back-to-back, while Option D specifies a totally randomized test matrix. Option D requires a higher level of effort and more test fuel than Option C.

It should be noted that the budget estimate attached to this Work Plan is for the first year of the contract only and assumes that Option A-C will be conducted. It also assumes that SwRI will be able to complete all testing during the second year of the project. SwRI understands that the options ultimately chosen by EPA will dictate the length and cost of the project. To aid EPA in selecting an appropriate combination of options, budgetary cost estimates for all option combinations (A-C, A-D, B-C, and B-D, with and without non-VOC measurements) are provided in Section 6.0. Details of the project are presented below.

### **3.1 Work Plan Development**

This document constitutes an initial Work Plan. It is understood that the work will proceed only upon the selection of a set of options by written technical direction from the WAM/PO.

This document assumes that this program will be conducted using Option A-C, and can be completed within two years. The detailed cost breakdown attached in Appendix B is for the first year of the contract. It assumes that vehicles and fuels will be available for the start of testing by the end of March 2008. Based on these assumptions, SwRI anticipates being able to conduct 360 tests at room temperature during the first year of the contract. If these assumptions are incorrect, or if EPA chooses a combination of options other than A-C, the budget for the first year of the contract will need to be adjusted. Such a situation would also require revision of the overall project schedule and budget.

### **3.2 Quality Assurance Project Plan and Quality Management Plan (QAPP/QMP)**

SwRI will submit a Quality Assurance Project Plan (QAPP) to the EPA Work Assignment Manager for approval. The QAPP will be submitted within five (5) weeks following approval of the Work Plan.

### **3.3 Vehicle Recruitment**

For Option A, SwRI will lease 19 test vehicles, all equipped with automatic transmissions and two-wheel drive, as listed in Table 1. New vehicles will be leased for a two-year period. It should be noted that the budget for the first year of the contract includes a commitment for the full two years of vehicle leases. Additionally, the attached cost estimate for the first year of the contract assumes the vehicles will not be kept beyond the expiration of the 2-year lease. This will be sufficient to accomplish Option A-C. However, if other options are requested it may become necessary to extend the vehicles leases beyond two years, which could result in the project incurring additional costs. In this case, the budget for the first year of the contract would need to be adjusted, since it is SwRI's intention to commit all funds for vehicle leasing up front. The attached budget assumes that vehicle leases will start in November 2007.

All vehicles will meet the requirements specified in Table 1; however, it is expected that all vehicle will be 2008 MY. It is anticipated that these vehicles will be of the same certification levels as listed for 2007 MY vehicles. However, SwRI will submit 2008 MY engine families to EPA for confirmation and approval prior to leasing any vehicles.

The Statement of Work indicates that vehicles must have a minimum of 4,000 miles on the odometer to eliminate any engine break-in issues. Because SwRI plans to lease new vehicles, they will all need to be brought to 4,000 odometer miles. This will be accomplished by operating the vehicles on mileage accumulation dynamometers using the Standard Road Cycle. It is expected that mileage accumulation will be accomplished using non-oxygenated commercial 87 octane regular unleaded gasoline available from a San Antonio distributor.

**TABLE 1. TEST VEHICLES FOR RECRUITMENT**

MAKE	YEAR	BRAND	MODEL	ENGINE	FAMILY	T2 BIN	NOTE
GM	2007	Chevrolet	Cobalt/HHR	2.4L I4	7GMXV02.4029	5	
GM	2007	Chevrolet	Impala	3.5L V6	7GMXV03.5052	5	FFV
GM	2007	Buick/GMC/Saturn	Enclave/Acadia/Outlook	3.6L V6	7GMXT03.6151	5	
GM	2007	Chevrolet/GMC	Avalanche	5.3L V8	7GMXT05.3381	4	FFV
Toyota	2007	Toyota	Corolla	1.8L I4	7TYXV01.8BEA	5	
Toyota	2007	Toyota	Camry	2.4L I4	7TYXV02.4BEB	5	
Toyota	2007	Toyota	Sienna	3.3L V6	7TYXT03.3BEM	5	
Toyota	2007	Toyota	Tundra	4.0L V6	7TYXT04.0AEV	5	
Ford	2007	Ford	Focus	2.0L I4	7FMXV02.0VD4	4	
Ford	2007	Ford	500/ Taurus/Freestyle	3.0L V6	7FMXV03.0VED	5	
Ford	2007	Ford/Mercury	Explorer/Mountaineer	4.0L V6	7FMXT04.03DB	4	
Ford	2007	Ford	F150	5.4L V8	7FMXT05.44H2	8	FFV
Chrysler	2007	Dodge	Caliber	2.4L I4	7CRXB0144M80	5	
Chrysler	2007	Dodge/Chrysler	Caravan/Town & Country	3.3L V6	7CRXT03.3NHP	8	FFV
Chrysler	2007	Jeep	Liberty	3.7L V6	7CRXT03.7NE0	5	
Honda	2007	Honda	Civic	1.8L I4	7HNXV01.8MKR	5	
Honda	2007	Honda	Accord	2.4L I4	7HNXV02.4KKC	5	
Honda	2007	Honda	Odyssey	3.5L V6	7HNXT03.5VKR or 7HNXT03.5WKR	5	either family
Nissan	2007	Nissan	Altima	2.5L I4	7NSXV02.5G5A	5	

Following mileage accumulation, a single FTP test will be performed on each vehicle with the regular unleaded gasoline used for mileage accumulation. Phase-level measurements of total hydrocarbon (THC), non-methane hydrocarbon (NMHC), oxides of nitrogen (NO<sub>x</sub>), carbon monoxide (CO), and carbon dioxide (CO<sub>2</sub>) emissions will be submitted to the EPA WAM for review to determine each vehicle's acceptability as a candidate for the test program. Vehicles must meet certification standards to be acceptable. If accepted by EPA, an approved candidate vehicle may begin preparations for testing as outlined in Section 3.6. SwRI and EPA agree that there is a

low probability of finding a vehicle that is unacceptable for this program. If such a case were to occur, the project would incur additional costs to remedy the situation.

For Option B, two of the 19 test vehicles will be designated for additional testing in a high-emitting configuration. This would be accomplished by forcing a malfunction, such as unplugging an O<sub>2</sub> sensor or removing a catalyst. If Option B is chosen, SwRI will propose test vehicles and malfunction modes for EPA's consideration and approval.

### **3.4 Test Lubricants**

Engine lubricants will be provided by the EPA per recommendations of a vehicle's manufacturer. SwRI will refer to the owners' manual of each vehicle for the proper lubricant viscosity. Based on the needs of the test program, SwRI will inform EPA of the necessary amounts of lubricant needed in each viscosity grade. These are expected to be 5W-20, 5W-30, and 10W-30. Once SwRI receives the test lubricants from EPA, a 1-quart sample will be collected from each drum of lubricant. All samples will be sent to a laboratory designated by the EPA WAM. After the last test of each vehicle in the program SwRI will measure and record the lubricant level indicated on the dipstick, after which a 1-quart lubricant sample will also be collected. These samples will also be sent to the same laboratory specified by EPA. No provisions for analyses of lubricant samples have been included in this Work Plan. It is assumed that EPA will independently arrange for the analyses of lubricant samples by the designated lab.

### **3.5 Test Fuels**

SwRI will procure and store all test fuels for this program. To date, only Haltermann Products has expressed a willingness and ability to provide the test fuels for this program. It is understood that there are two different fuel matrices that EPA would like to consider for testing: Option A and Option B.

Option A of the program will include 17 test fuels as given in Appendix A of the Statement of Work. All 19 vehicles will be tested on all fuels under this option following the preparation and testing protocols detailed in Sections 3.6 and 3.7 below.

Option B includes 23 fuels. 21 of these fuels will be tested in all vehicles. It is understood that two of the fuels will be E85 blends, and will be tested only in the 4 FFVs. In addition to the 19 vehicles to be tested under Option A, two of the test vehicles will be designated for additional testing in a high-emitting configuration (as explained in Section 3.3 above). Thus, a total of 21 fuels will be tested in 21 vehicles, while an additional 2 high-ethanol blends will be tested in the 4 FFVs.

To date, SwRI has been provided with detailed specification only for the Option A fuels. At this point in time, Haltermann has provided only budgetary estimates for the cost of test fuels. Additionally, in the case of Option B, SwRI has made "worst-case" estimates for the cost of procuring test fuels. Thus, the actual cost of the test fuels may vary from what is estimated in the attached budget. It should also be noted that the attached budget for the first year of the contract

assumes that only the 17 fuels given in Option A will be tested. If additional fuels beyond those given in Option A are to be tested, these would also need to be procured during the first year of the contract, which would require a revision to the budget. The attached budget assumes that fuels will be delivered, approved, and available for testing by the end of March 2008.

SwRI has indicated to Haltermann that test fuels will be blended exclusively from refinery components and cuts of refinery components. Special chemicals and chemical blendstocks will not be used. However, butane and benzene may be used to adjust RVP and benzene content of these fuels, respectively. Furthermore, sulfur content of the fuels may be adjusted using a three-component sulfur mixture containing 4.3 mass % of dimethyl disulfide, 22.8 mass % of thiophene and 72.9 mass % of benzothiophene. An oxidation inhibitor will be added to all finished test fuels. Haltermann has indicated that they expect to be able to meet these requirements.

Hand blend inspection data for every test fuel will be presented to the EPA WAM for review. Final blending will not proceed unless authorized by the EPA WAM. Final blend inspection data generated by Haltermann will be forwarded to the EPA WAM for review prior to the shipment of these fuels for use in the emissions test program. The shipment of the fuels to SwRI and their use in this program will not proceed unless authorized by the EPA WAM. Once the fuels are received, SwRI will conduct a complete set of analyticals (to be determined) on a single drum sample of each fuel. Additional analyticals will be conducted on a single drum sample of each fuel at the midpoint and end of the program to determine whether any fuel properties have changed as a result of fuel storage and handling.

To assure that no drums are mislabeled, fuel properties will be confirmed when each drum is opened using a Petrospec analyzer. Additionally, all drums will be receive a unique alphanumeric label and each time a vehicle is fueled the alphanumeric code will be recorded.

Once a fuel has been accepted for testing, a 5 gallon sample will be shipped to EPA for use in an audit and/or a round robin program.

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### **3.6 Vehicle Preparation**

Although these will be new vehicles, they will undergo inspection after odometers have been brought up to 4,000 miles. This will include inspection of the engine, transmission, axles, exhaust system and tires, and verification that no OBD2 faults are set. Additionally, vehicle information will be collected and recorded for entry into MSOD data tables, as described in Appendix C of the Statement of Work.

If a vehicle is equipped with traction control, it will be disabled either through an interior disable button or other method (remove power fuse to anti-lock brake system (ABS)), and a placard will be placed in the vehicle indicating the method of disabling traction control if driver input is required.

Chassis dynamometer setting will be derived from target road load coefficients as reported in EPA's on-line Test Car List Data Files. Each vehicle will use the same chassis dyno settings during both 75°F and 50°F tests. Target road load coefficients and subsequently-derived chassis dyno settings will be submitted to the EPA WAM for approval prior to the initiation of testing.

After each vehicle is accepted into the test program following mileage accumulation to bring all vehicles up to 4,000 odometer miles, it will undergo initial crankcase oil, oil filter, and air filter replacements. Oil and air filters will be procured by SwRI per manufacturer's recommendations. Oil will be drained and replaced with one of the EPA-supplied lubricants per the vehicle manufacturer's viscosity requirements. For each vehicle, the lubricant level in the sump will be allowed to stabilize and its level indicated on the dipstick will be recorded. Each vehicle will then be driven for 500 miles on commercial unleaded gasoline to condition the lubricant in preparation for the emissions test program. Mileage will primarily be on local interstates at or below posted speed limits. This Work Plan, and the associated budget for the first year of the contract, assumes that all vehicle preparation will be completed by the end of March 2008.

### **3.7 Vehicle Testing**

All vehicles will be tested on all test fuels using the California Unified Cycle (LA92). For this program, the LA92 will be conducted as a three-phase, cold-start test in a manner similar to the FTP, including ambient and load conditions. All tests on a given vehicle will be conducted using the same 48-inch single roll electric chassis dynamometer. It is expected that a single test site will be used for this entire program. The same driver will be used for all tests on a given vehicle; however, it may be necessary to use more than one driver in the program.

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The attached budget assumes that SwRI will conduct 360 room-temperature tests in the first year of the contract. This is contingent on the test fuels being delivered, approved, and available for testing by the end of March 2008. If the start of testing is delayed beyond the beginning of April 2008, it will not be possible to conduct 360 tests in the first year of the contract, and a revision to the first-year budget will be necessary.

EPA has requested that two test options be considered in conjunction with fuel matrix Options A and B:

### **3.7.1 Option C**

Under this Option, SwRI will follow the fuel change and test execution sequence as described in Table 2 below. The order in which the various test fuel and vehicle combinations are to be tested will be randomized. However, replicate tests of a given fuel in a particular vehicle will be done back-to-back. The second replicate will be run in the same way as the first except that only THC, NMHC, CO, CO<sub>2</sub>, NO<sub>x</sub>, NO (for determination of NO<sub>2</sub> by difference), ethanol, and PM emissions will be measured. If the difference between any of the criteria pollutant measurements is greater than variability criteria to be provided by EPA, on the following day a third replicate will be run in the same way as the second. This “back-to-back” testing eliminates the need to repeat additional vehicle preconditioning between each replicate test on a given fuel. A separate cost estimate for employing this option in conjunction with both Options A and B is given in Section 6.0 below.

**TABLE 2. FUEL CHANGE AND TEST EXECUTION SEQUENCE FOR OPTION C**

<b>STEP</b>	<b>DESCRIPTION</b>
1	Drain vehicle fuel completely via fuel rail whenever possible
2	Turn vehicle ignition to RUN position for 30 seconds to allow controls to allow fuel level reading to stabilize. Confirm the return of fuel gauge reading to zero
3	Fill fuel tank to 40% with next test fuel in sequence. Fill-up fuel must be at the temperature of the next LA92 test (75 or 50°F)
4	Start vehicle and execute catalyst sulfur removal procedure described in Appendix C of CRC E-60 Program report
5	Drain fuel and refill to 40% with test fuel. Fill-up fuel must be at the temperature of the next LA92 test (75 or 50°F)
6	Start vehicle and drive one LA4 cycle. Allow vehicle to idle in park for 2 minutes before engine shut-down
7	Move vehicle to soak area without starting or driving
8	Park vehicle in soak area at proper temperature (75 or 50°F) for 12-36 hours
9	Move vehicle to test area without starting engine
10	Perform LA92 cycle emissions test
11	Park vehicle in soak area of proper temperature for 12-36 hours
12	Move vehicle to test area without driving
13	Perform LA92 emissions test
14	Determine whether third replicate is necessary, based on data variability criteria (see Table 6.1-3 below)
15	If a third replicate is required, repeat steps 10, 11 and 12
16	If third replicate is not required, return to step 1 and proceed with next fuel in test sequence

### **3.7.2 Option D**

As a contrast to Option C, under this option all exhaust emission tests on a given vehicle, including replicates, will be conducted in a random order (see Table 3). All replicates on a given fuel will be run in the same way as the first emissions test except that only THC, NMHC, CO, CO<sub>2</sub>, NO<sub>x</sub>, NO (for NO<sub>2</sub> determination), ethanol, and PM emissions will be measured. If the first two emission tests performed on a given fuel do not meet the variability criteria to be provided by EPA, a third replicate will be added to the remaining random test sequence. The third test would be run in

the same way as the second. This will require more frequent vehicle preconditioning between fuel changes but may result in a more preferable experimental design from a statistical point of view. A separate cost estimate for employing this option in conjunction with both Options A and B is given in Section 6.0 below.

**TABLE 3. FUEL CHANGE AND TEST EXECUTION SEQUENCE FOR OPTION D**

STEP	DESCRIPTION
1	Drain vehicle fuel completely via fuel rail whenever possible
2	Turn vehicle ignition to RUN position for 30 seconds to allow fuel level reading to stabilize. Confirm the return of fuel gauge reading to zero
3	Fill fuel tank to 40% with next test fuel in sequence. Fill-up fuel must be at the temperature of the next LA92 test (75 or 50°F)
4	Start vehicle and execute catalyst sulfur removal procedure described in Appendix C of CRC E-60 Program report
5	Drain fuel, and refill to approximately 40% with test fuel. Fill-up fuel must be at the temperature of the next LA92 test (75 or 50°F)
6	Start vehicle and drive one LA4 cycle. Allow vehicle to idle in park for 2 minutes before engine shut-down
7	Move vehicle to soak area without starting or driving
8	Park vehicle in soak area at proper temperature (75 or 50°F) for 12-36 hours
9	Move vehicle to test area without starting engine
10	Perform LA92 emissions test
11	Return to step 2 to prepare for next fuel under the fully randomized test schedule

Regardless of the option chosen, additional cold temperature testing at 50°F (nominal) will be conducted for all non-FFV vehicles in the test fleet on a subset of 4 test fuels (to be identified by the EPA WAM prior to procuring fuels). Testing at 50°F will be conducted as a block. It is anticipated that the 50°F tests will be conducted following the completion of all room-temperature testing. As such, the first-year budget contains no provisions for conducting 50°F tests. SwRI will

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Phase-level (bag-by-bag) emissions to be measured and reported for all tests are:

- total hydrocarbons (THC)
- non-methane hydrocarbons (NMHC)
- oxides of nitrogen (NO<sub>x</sub>)
- nitrogen dioxide (NO<sub>2</sub>) will be determined by the difference of measured NO and NO<sub>x</sub> values – expected detection limit approximately 50 ppb
- carbon monoxide (CO)
- carbon dioxide (CO<sub>2</sub>)
- particulate matter (PM)
- ethanol

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Additionally, phase-level (bag-by-bag) level speciated VOCs will be measured and for a subset of tests as follows:

- Option A: For 3 vehicles (to be selected by the EPA WAM prior to the start of testing), all 3 phases on all fuels. It is currently anticipated that these tests would be part of the random test matrix. However, SwRI understands that EPA may be interested in conducting these tests prior to those requiring speciation on only Phase 1 of the LA92. Such a modification to the test plan would require an adjustment to the test schedule and the budget for the first year of the contract. For the remaining 16 vehicles, VOCs will be determined for only Phase 1 of the LA92 test (for all test fuels). This will be performed on the first tests at 75°F only (no repeat speciations are required).
- Option B: VOC speciation will be performed for all 3 phases of the first LA92 test on each vehicle and fuel combination at 75°F only. No repeat speciations are required. With this option, SwRI would be limited to testing a maximum of 4 cars per day with speciation, which could impact the schedule. Note that the first-year budget attached to this Statement of Work assumes Option A. Selection of Option B would require a revision to the budget for the first year of the contract.

VOC speciation will include C<sub>1</sub>-C<sub>12</sub> hydrocarbons as well as light alcohols, aldehydes, and ketones. Sampling and analysis of C<sub>2</sub>-C<sub>12</sub> hydrocarbons will be conducted in a manner similar to CARB method 1002/1003, "Procedure for the Determination of C<sub>2</sub>-C<sub>12</sub> Hydrocarbons in

Automotive Exhaust Samples by Gas Chromatography”. Sampling and analysis of carbonyl compounds will be conducted in a manner similar to CARB method 1004, “Determination of Aldehyde and Ketone compounds in Automotive Source Samples by High Performance Liquid Chromatography”. Analysis of C<sub>1</sub> – C<sub>4</sub> HC samples will be done within one hour of completion of the emissions test. Subsequent analysis of the additional compounds of interest will be done within 4 hours of emission test completion. The time between sample collection and the start of C<sub>1</sub>-C<sub>4</sub> HC analysis will be reported. The VOCs to be analyzed are identified in Appendix D of the Statement of Work.

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Each vehicle will be tested at least twice on a given fuel regardless of option selection. After two tests have been completed and the acquired data has passed all quality control verifications, , the need for a third test will be determined by following variability criteria (for NMHC, CO, NO<sub>x</sub>, and CO<sub>2</sub>), to be provided by EPA prior to the start of testing. If a third test is needed, the EPA WAM will be notified (typically within 24 hours) and the summary data for the test pair in question will be provided. For budgeting purposes, this Work Plan assumes that 5 percent of all test pairs will require a third test. If the actual need to conduct a third test exceeds the 5-percent allocation, the project will incur additional costs.

As an option to be conducted following completion of all room-temperature and 50°F testing listed above, the following non-VOC compounds would be measured and reported:

- EC/OC PM integrated over the whole test cycle for a subset of tests
- Continuous PM by QCM and equilibrated PM by bag (phase) for a subset of tests
- Continuous particulate size and number by EEPS for a subset of tests
- SVOCs integrated over the whole test cycle for a subset of tests.
- Metals integrated over the whole test cycle for a subset of tests.
- Sulfate, chloride and nitrate ions integrated over the whole test cycle for a subset of tests.
- Continuous and integrated by bag (phase) emissions of the following species measured in raw exhaust for a subset of tests: N<sub>2</sub>O, NH<sub>3</sub> and HCN.

These optional measurements would be conducted as follows:

- Option A: six (6) vehicles on two (2) fuels
- Option B: twelve (12) vehicles on six (6) fuels.

Optional non-VOC measurements would be conducted once for each fuel/vehicle combination, and only at room temperature. The estimated budget given in this Work Plan assumes that conventional CVS sampling methods would be used for sample collection, and that non-VOC measurements could be completed during the second year of the contract. However, based on ongoing conversations between EPA and SwRI, it is understood that EPA's requested scope for non-VOC measurements is likely to change substantially. Thus, SwRI will address the details of non-VOC sampling and measurement methods at a future point in time. Depending on EPA's requested changes in scope for non-VOC sampling and analyses, the impact on the schedule and budget could be substantial.

#### **4.0 REPORTING AND DELIVERABLES**

##### **4.1 Weekly Reports**

SwRI will conduct weekly 30-60 minute telephone conference calls with the WAM or her designate that summarize progress to date. These weekly calls are currently scheduled for Tuesday mornings at 10AM Eastern / 9AM Central. When appropriate, weekly test results in spreadsheet form will be provided to the EPA WAM.

##### **4.2 Monthly Written Progress Reports**

SwRI will provide monthly progress reports. Invoices will be provided every four weeks according to the existing contract. The monthly progress reports will include information from the most recent invoice. The reports will track percentages of hours used in each task and whether the project is on schedule. They will explain problems encountered including resolutions and indicate if the schedule or budget is affected.

##### **4.3 Data Files**

SwRI will submit the data to EPA in three formats, each format having different levels of post processing and aggregation. The files are nominally:

1. Non-Post processed data files (raw data): These are the native test level data files, usually generated by instrumentation, that have not been post-processed for such purposes as time-series alignment or calculation of continuous emission rates. They will be submitted to EPA as a deliverable for this work assignment and labeled using the following convention:

*'e'<VehID>\_<fuelID>\_raw.<extension>*

where *VehID* is the unique identifier designated for vehicle, *fuelID* is the unique identifier assigned to each fuel type, and *extension* is the appropriate file extension for the file's data format. Modifications to the specified file-naming convention may be adopted following approval from the EPA Work Assignment Manager.

2. Post processed data files: These are the minimally processed test level data files that will contain the composite, test level, bag level, and 1 Hertz (modal) emission rates in the units

‘e’<*VehID*>\_<*fuelID*>\_pst.<*extension*>

where *VehID* is the unique identifier designated for vehicle, *fuelID* is the unique identifier assigned to each fuel type, and *extension* is the appropriate file extension for the file’s data format. Modifications to the specified file-naming convention may be adopted following approval from the EPA WAM.

3. SwRI will also deliver Mobile Source Observation Database (MSOD) input data files containing test results and vehicle information using table names, structures, field names and field formats as specified in Appendix C of the Statement of Work. During the program it may be necessary to design and apply new data types, tables and structures. As necessary, such modifications to the data structure would be approved by the EPA WAM.

#### **4.4 Mode of Delivery**

SwRI will deliver one set of files to the EPA WAM at the USEPA National Vehicle and Fuel Emissions Laboratory at Ann Arbor, Michigan. Data contained in the MSOD formatted tables will be submitted via a secure method to be approved by the WAM. Under no circumstances will these files be delivered by insecure methods such as electronic mail attachments or First Class Mail.

#### **4.5 Draft Final Report**

SwRI will submit a draft final report to EPA within six weeks following the completion of all testing under this Work Assignment.

#### **4.6 Final Report**

SwRI will provide a final report incorporating EPA comments, within 30 days of receiving comments from EPA. The report will be in hard copy plus an agreed-upon electronic format such as Microsoft Word or Adobe portable document files (\*.pdf).

### **5.0 STAFF ASSIGNMENTS**

The SwRI Work Assignment Manager and Principal Investigator will be Kevin Whitney. Mr. Patrick Merritt will be the alternate Work Assignment Manager and E. Robert Fanick will manage VOC emissions analyses.

### **6.0 PROJECTED LABOR HOURS AND OTHER DIRECT COSTS**

Based on our understanding of Work Assignment 0-01, we project the breakdown of employee utilization by labor category as detailed in Table 4 for the first year of the contract. Complete cost detail for the first year’s effort is presented in the attached cost breakdown shown in Appendix B. Estimates for other direct costs are shown in Table 5. Table 6 contains cost estimates for all options detailed in this Work Plan.

**TABLE 4. PROJECTED LABOR HOURS FOR  
WORK ASSIGNMENT 0-01; FIRST YEAR OF CONTRACT**

LABOR CATEGORY	NUMBER OF HOURS
PL4	<b>Ex. 4 - CBI</b>
PL3	
PL2	
PL1	
Senior Technical	
Technical	
Clerical	
<b>Total</b>	
<b>Total Technical Hours</b>	

**TABLE 5. PROJECTED OTHER DIRECT COSTS  
FOR WORK ASSIGNMENT 0-01; FIRST YEAR OF CONTACT**

ITEM	PROJECTED OTHER DIRECT COSTS
24-month vehicle lease for 19 vehicles	<b>Ex. 4 - CBI</b>
8400 gallons test fuel	
Misc	
Fuel analyses	
3800 gallons fuel	
Span Gases	
Nitrogen, zero air	
Tedlar bags	
Exhaust pipe, flanges	
Swedgelock fittings	
Steel and teflon tubing	
Misc. mechanical	
Misc. electrical	
Durability fuel	
Vehicle maintenance sets	
Particulate Filters	
Chart paper	
Glassware	
GC supplies	
<b>TOTAL</b>	



**TABLE 6. BUDGETARY COST ESTIMATE FOR OPTIONS**

OPTION	A	B
C	<b>Ex. 4 - CBI</b>	
D		
Optional non-VOCs (not included above)		

## 8.0 EXCEPTIONS

Given the constraints of the Work Assignment and the Contract, and to account for some additional technical considerations, SwRI has proposed to make the following exceptions to activities specified in Work Assignment 0-01:

**8.1** All vehicles will meet the requirements specified in Table 1; however, it is expected that all vehicle will be 2008 MY. It is anticipated that these vehicles will be of the same certification levels as listed for 2007 MY vehicles. However, SwRI will submit 2008 MY engine families to EPA for confirmation and approval prior to leasing any vehicles.

an not

**Ex. 4 - CBI**

**Ex. 4 - CBI**

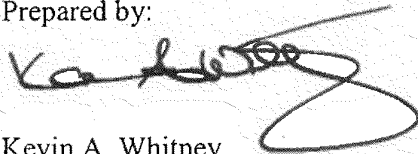
8.5 All measurements and analyses of non-VOC compounds as listed under 6.3, 6.4, 6.5, 6.6, 6.7, and 6.8.2 of the Statement of Work are offered as an option to be conducted following completion of all room-temperature and 50°F testing.

8.6 SwRI will provide prototype electronic data file types for the inspection and approval of the EPA WAM under separate cover.

## 9.0 SUMMARY

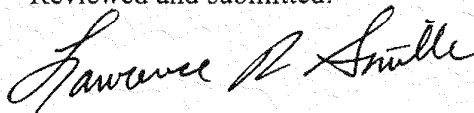
Southwest Research Institute has responded to Work Assignment 0-01 with exceptions as noted in Section 8.0 above. Should any questions of a technical nature arise, please contact Mr. Kevin Whitney at 210-522-5869 or Mr. Patrick Merritt at 210-522-5422. If there are questions regarding cost or contractual issues, please contact Ms. Sherry Twilligear at 210-522-3948. Thank you for this opportunity to be of service.

Prepared by:



Kevin A. Whitney  
Manager, Light-Duty Vehicle Emissions  
Spark Ignition Powertrain Department

Reviewed and submitted:



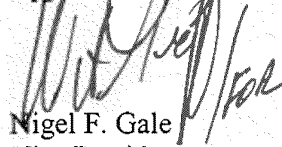
Lawrence R. Smith  
Manager, Chemistry & Unregulated Emissions  
Engine Design and Development Department

Approved:



for Franz Laimboeck  
Program Director, Spark Ignition Powertrain  
Department  
Engine, Emissions, and Vehicle Research  
Division

Approved:



Nigel F. Gale  
Vice President  
Engine, Emissions, and Vehicle Research  
Division

c: Mr. Carl Scarbro, EPA-AA  
Ms. Constance Hart, WAM, EPA-AA  
Ms. Sherry Twilligear, SwRI Contracts

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**APPENDIX A**

**STATEMENT OF WORK, WORK ASSIGNMENT 0-01**

**U.S. ENVIRONMENTAL PROTECTION AGENCY**

## **Performance Work Statement**

Contract EP-C-07-018	Work Assignment Number 01 Amendment 1
Issuing Office	Environmental Protection Agency 2000 Traverwood Drive Ann Arbor, MI 48105-2498
Contractor	Southwest Research Institute 6220 Culebra Rd. San Antonio, TX 78228-0510
Title	Comprehensive Gasoline Light Duty Exhaust Fuel Effects Test Program to Cover Multiple Fuel Properties and Two Ambient Test Temperatures

This amendment to work assignment 0-1 supplants the original performance work statement.

### **Background**

Section 1506 of the Energy Policy Act of 2005 (Energy Act) requires EPA to produce an updated fuel effects model representing the 2007 light duty gasoline fleet, including determination of the emissions impacts of increased renewable fuel use.

The use of ethanol in gasoline has increased more than five-fold since 2000, and it is likely that its use will continue to expand into the next decade. It is also likely that use of high-level blends such as E85 will expand significantly.

Recent investigation related to the Mobile Source Air Toxics (MSAT2) rulemaking has shown that hydrocarbon emissions from light duty gasoline vehicles increase significantly as test temperature is decreased. As a result, the MSAT2 rulemaking promulgated NMHC standards at 20°F. However, this being a relatively new area of study, fuel effects data at temperatures lower than 75°F is scarce for use in emissions models.

Hydrocarbon (HC) emissions are composed of hundreds of compounds, some of which have been identified by the EPA as air toxics. The Clean Air Act directs EPA to set standards to reduce air toxics emissions. Most existing data on the fractional relationship between the various air toxics and HC emissions has been established using vehicles meeting Tier 0 emissions standards (now more than 10 years old), and burning fuels that did not contain ethanol.

### **Scope and Objectives**

This Work Assignment (WA) has been designed to fill significant data gaps on fuel effects for the newest-technology (Tier 2) vehicles:

- Multiple levels of ethanol in gasoline shall be examined in this test program, along with

- ethanol's interactions with other fuel properties, e.g. volatility and distillation parameters.
- Varying levels of aromatics shall also be evaluated, as they continue to be of interest due to their relationship to emissions of air toxics and the formation of particulate matter in the atmosphere.
- A portion of the tests shall be performed at 50°F to fill the gap in the existing data at reduced ambient temperatures.
- This program shall also generate speciated VOC data from newer (i.e. Tier 2) vehicles while operated on all test fuels. VOC compounds of interest include C1 – C12 hydrocarbons as well as light alcohols, aldehydes, and ketones. This is in addition to the standard HC FID measurements.
- PM mass shall be measured for each test, with limited PM speciation carried out for a subset of tests as described in Task 6 of this document. This speciation shall include measurement of elemental and organic carbon. Continuous PM mass and particle count/sizing techniques shall also be employed.

The contractor shall perform vehicle preparation and driving tests to generate analytical data on exhaust gas emissions. The contractor shall generate electronic reports and databases, as well as quality assurance documentation.

### Work Requirements

This work assignment requires that the contractor procure 19 suitable test vehicles with certain specifications (as detailed below). The number of fuels to be tested ranges from 17 to 23, depending on the option selected. The contractor shall procure these fuels. The number of fuels will ultimately determine the required number of tests and therefore the total cost of the program, so EPA requests that the contractor provide separate cost estimates for Options A and B, below.

The contractor shall be responsible for providing engineering, technical, and Quality Assurance (QA) support for this project. Engineering support includes facility design, test plan development, and general oversight of data collection activities. Technical support includes installing and maintaining all instrumentation and support equipment, as well as calibration, testing, and data processing activities. QA support includes reviewing existing standard operating procedures (SOPs), preparing QA documentation, developing miscellaneous operating procedures (MOPs), and reviewing raw and processed data prior to delivery to EPA.

### **Task 1 Work Plan Development**

The contractor shall submit a detailed work plan for EPA approval. The work plan shall include a detailed description of how the tasks described below are to be performed, including details such as toxics and PM measurement methodology. The work plan shall include suggested alternatives for any of the required tests or procedures if such alternatives are thought to result in higher quality results.

This work assignment lists several testing/fuel options (Options A and B for additional fuel, vehicle, and measurement frequencies and testing protocol Options C and D for two separate methods for performing test repeats). The work plan costs shall be broken down by task and

sub-task for each of these options (in other words one cost estimate for fuels Option A exercising Option C, one with Option A exercising Option D, one with fuels Option B exercising Option C, and one with Option B exercising Option D). Thus a total of 4 option scenarios are thus possible and will require separate cost estimates. The work performed shall be based upon the WAM/PO evaluation of each of the four options presented in the work plan, The work shall proceed only upon the the selection of an option by written technical direction from the WAM/PO.

The project work plan shall include descriptions of each task to be accomplished, along with detail on the level of effort, by professional grade, a cost breakdown for each task, and any information on the underlying assumptions used in arriving at these cost estimates. The contractor shall conduct necessary activities to properly and efficiently manage the work assignment, including at least weekly communication with the EPA WAM. The contractor shall also include a list of any facility issues or upgrades that may be needed to implement this work assignment.

This work is projected to cover a period of up to two years. Therefore the work plan must break down costs to indicate what can be reasonably accomplished during this initial contract year. It is anticipated that the contractor shall be capable of doing 150 tests against this scope of work during this contract year.

## **Task 2 Quality-Assurance Project Plan and Quality Management Plan (QAPP/QMP)**

The contractor shall submit a Quality Assurance Project Plan (QAPP) to the EPA Work Assignment Manager for approval. The plan shall detail sample data collection and analysis tasks and procedures for the proposed study. Guidance for QAPP preparation is available at <http://www.epa.gov/quality/qapps.html>. The QAPP shall be approved by the EPA WAM before any work commences.

The Quality-Assurance Project Plan shall specify the procedures required to collect data in a manner consistent with the objectives of the study. The plan will be developed in consultation with the EPA Work Assignment Manager. The QAPP documents shall conform to the EPA ANSI/ASQC E-4 standard and shall contain appendices containing all applicable standard operating procedures (SOPs).

In the QAPP, the contractor shall describe measures designed to ensure data quality, including but not limited to:

- Standard operating procedures for equipment used to perform calibrations.
- Calibration frequency and schedule for all equipment used in testing (analyzers, dynamometer, chemical speciation equipment).
- Procedures for sampling and recruitment.
- Procedures for data transfer, entry and management.
- Procedures for regular transfer of all data generated in this project to the EPA Work Assignment Manager for review/audit, consistent with Task 7.3 of this Statement of Work.

## **Task 3 Vehicle Recruitment**

The contractor shall acquire (through lease, purchase, or alternate recruitment technique approved by the EPA WAM) 19 test vehicles from the in-use fleet in the local area. All of these vehicles must have been originally certified and sold as being compliant with the Federal Tier 2 emissions standards, and shall be selected (in any order) from the vehicles listed in Table 3-1 . Of these vehicles, 4 must be flexible-fueled vehicles (FFVs) of differing models capable of operation on ethanol-gasoline blends up to and including 85% ethanol (E85). The vehicles must be equipped with an automatic transmission, and shall have a minimum of 4,000 miles on the odometer to eliminate any engine break-in issues and a maximum of 20,000 miles (exceptions must be approved by the EPA WAM). The vehicle shall be in good operating condition with no engine, transmission or emission system malfunctions indicated or observed. Table 3-1 lists the target vehicles for recruitment. In cases where multiple vehicle models are listed for a given model year engine family, any model within that family may be selected.

**Table 3-1. Test Vehicles for Recruitment**

<b>Make</b>	<b>Year</b>	<b>Brand</b>	<b>Model</b>	<b>Engine</b>	<b>Family</b>	<b>T2 Bin</b>	<b>Note</b>
GM	2007	Chevrolet	Cobalt/HHR	2.4L I4	7GMXV02.4029	5	
GM	2007	Chevrolet	Impala	3.5L V6	7GMXV03.5052	5	FFV
GM	2007	Buick/GMC/Saturn	Enclave/Acadia/Outlook	3.6L V6	7GMXT03.6151	5	
GM	2007	Chevrolet/GMC	Avalanche	5.3L V8	7GMXT05.3381	4	FFV
Toyota	2007	Toyota	Corolla	1.8L I4	7TYXV01.8BEA	5	
Toyota	2007	Toyota	Camry	2.4L I4	7TYXV02.4BEB	5	
Toyota	2007	Toyota	Sienna	3.3L V6	7TYXT03.3BEM	5	
Toyota	2007	Toyota	Tundra	4.0L V6	7TYXT04.0AEV	5	
Ford	2007	Ford	Focus	2.0L I4	7FMXV02.0VD4	4	
Ford	2007	Ford	500/new Taurus/Freestyle	3.0L V6	7FMXV03.0VED	5	
Ford	2007	Ford/Mercury	Explorer/Mountaineer	4.0L V6	7FMXT04.03DB	4	
Ford	2007	Ford	F150	5.4L V8	7FMXT05.44H2	8	FFV
Chrysler	2007	Dodge	Caliber	2.4L I4	7CRXB0144M80	5	
Chrysler	2007	Dodge/Chrysler	Caravan/Town & Country	3.3L V6	7CRXT03.3NHP	8	FFV
Chrysler	2007	Jeep	Liberty	3.7L V6	7CRXT03.7NE0	5	
Honda	2007	Honda	Civic	1.8L I4	7HNXV01.8MKR	5	
Honda	2007	Honda	Accord	2.4L I4	7HNXV02.4KKC	5	
Honda	2007	Honda	Odyssey	3.5L V6	7HNXT03.5VKR	5	either family
					7HNXT03.5WKR		cylinder deact.
Nissan	2007	Nissan	Altima	2.5L I4	7NSXV02.5G5A	5	

Option B includes 2 additional “high emitter” vehicles to be identified by the EPA WAM at a later date.

All candidate vehicles recruited by the contractor shall be inspected and prepared for testing according to the methodology outlined in Task 5. A single FTP test shall then be performed using a baseline fuel (TBD) with bag measurements of total hydrocarbon (THC), non-methane hydrocarbon (NMHC), oxides of nitrogen (NO<sub>x</sub>), carbon monoxide (CO), and carbon dioxide (CO<sub>2</sub>) emissions. The results of this initial test shall be submitted to the EPA WAM for review to determine the vehicle’s acceptability as a candidate vehicle for the test program. If accepted by EPA, an approved candidate vehicle may begin preparations for testing as outlined below.

#### **Task 4 Test Fuels and Lubricants**

Engine lubricants will be provided by the EPA per recommendations of the vehicle manufacturers. At the outset of the program, the contractor shall take a 1 quart lubricant sample from each drum of lubricant supplied and forward all samples to the laboratory designated by the EPA WAM. The contractor shall take an additional 1 quart lubricant sample from each vehicle immediately following its last emissions test in this program and forward the sample for analysis to the same laboratory. EPA will arrange for sample analysis.

The contractor shall procure and maintain all test fuels for this program. Detailed specification of these fuels is provided in Appendices A and B for Options A and B, respectively. Their simplified target specifications are listed in Tables 4-1 and 4-2.

The test fuels shall be blended exclusively from refinery components and cuts of refinery components. Special chemicals and chemical blendstocks shall not be used. However, butane and benzene may be used to adjust RVP and benzene content of these fuels, respectively. Furthermore, sulfur content of the fuels may be adjusted using a three-component sulfur mixture containing 4.3 mass % of dimethyl disulfide, 22.8 mass % of thiophene and 72.9 mass % of benzothiophene. All blendstocks used in this program must be approved by the EPA WAM. An oxidation inhibitor shall be added to all finished test fuels.

Hand blend inspection data for every test fuel shall be presented to the EPA WAM for review. Final blending shall not proceed unless authorized by the EPA WAM. Similarly, final blend inspection data generated by the blending laboratory (in the event that fuel blending will be subcontracted), and by the contractor, shall be forwarded to the EPA WAM for review prior to the shipment of these fuels for use in the emissions test program. The shipment of the fuels to the contractor and their use in this program shall not proceed unless authorized by the EPA WAM.

Once a fuel has been accepted for testing, a 5 gallon sample shall be shipped to EPA for use in an audit and/or a round robin program. At least one additional analysis of each fuel shall be performed by the contractor at an interim point in the test program and/or at the end of the test program to determine whether any fuel properties have changed as a result of fuel storage and handling.



The contractor shall utilize fuel storage and handling practices that will minimize, to the greatest extent possible, any changes in test fuel properties (i.e. by storing the fuel in sealed drums in a temperature controlled environment), or mislabeling of fuel drums, or any other possible situations which could lead to misfueling of the test vehicles. Similarly, the contractor shall ensure that the fuel blending subcontractor (if any) will apply equally stringent fuel storage and handling practices to finished test fuels waiting for shipment. The contractor shall describe the methods to be employed to minimize such changes, and recommend additional methods that would prevent changes in fuel properties during the test program.

### Option A

Under this option the program will include 17 test fuels (see Table 4-1). All 19 vehicles shall be tested on all fuels under this option following the preparation and testing protocols detailed in Tasks 5 and 6, below.

**Table 4-1. Test Fuel Target Specifications for Option A**

Fuel ID	Ethanol (vol %)	T50 (°F)	T90 (°F)	RVP (psi)	Aromatics (corr. Vol %)
1	0	195	300	9	15
2	0	195	300	9	40
3	10	195	300	7	40
4	0	195	350	7	15
5	0	195	350	7	40
6	10	195	350	9	15
7	0	215	300	7	15
8	0	235	350	9	40
9	10	215	300	9	15
10	10	215	300	9	40
11	0	215	350	9	40
12	10	215	350	7	40
13	10	215	350	7	15
14	0	235	300	7	40
15	10	235	300	7	15
16	0	235	350	9	15
17	10	235	350	9	40

### Option B

Option B includes 23 fuels. 21 of these fuels will be tested in all vehicles, while the remaining 2 fuels are only tested on the 4 FFVs (these 2 fuels will be high-level ethanol blends). Table 4-2, below, lists the test fuel property requirements under this option. In addition to the 19 vehicles required under Option A, 2 high emitting vehicles shall be procured and tested on 21 of these fuels (all but the 2 high-level ethanol blends).

**Table 4-2. Test Fuel Target Specifications for Option B**

Fuel ID	Ethanol (vol %)	T50 (°F)	T90 (°F)	RVP (psi)	Aromatics (corr. Vol %)
1	0	TBD	TBD	TBD	TBD
2	0	TBD	TBD	TBD	TBD
3	20	TBD	TBD	TBD	TBD
4	20	TBD	TBD	TBD	TBD
5	0	TBD	TBD	TBD	TBD
6	85	Report	Report	Report	Report
7	0	TBD	TBD	TBD	TBD
8	85	Report	Report	Report	Report
9	20	TBD	TBD	TBD	TBD
10	20	TBD	TBD	TBD	TBD
11	20	TBD	TBD	TBD	TBD
12	0	TBD	TBD	TBD	TBD
13	10	TBD	TBD	TBD	TBD
14	10	TBD	TBD	TBD	TBD
15	10	TBD	TBD	TBD	TBD
16	0	TBD	TBD	TBD	TBD
17	20	TBD	TBD	TBD	TBD
18	10	TBD	TBD	TBD	TBD
19	10	TBD	TBD	TBD	TBD
20	10	TBD	TBD	TBD	TBD
21	10	TBD	TBD	TBD	TBD
22	10	TBD	TBD	TBD	TBD
23	0	TBD	TBD	TBD	TBD

### Task 5 Vehicle Preparation

Vehicles shall undergo a thorough inspection before beginning the test preparation sequence. This includes inspection of the engine, transmission, axles, exhaust system and tires, and verification that no OBD2 faults are set. The contractor shall collect and record vehicle information described in Appendix C for entry into MSOD data tables.

If the vehicle is equipped with traction control, ensure that it is disabled either through an interior disable button or other method (remove power fuse to anti-lock brake system (ABS)), and place a placard in the vehicle indicating the method of disabling traction control if driver input is required. The vehicle shall use a 75°F road load horsepower setting derived from the coastdown coefficients as proposed by the contractor and approved by the EPA WAM. For the purpose of this study, the agreed road load setting shall remain the same for all testing including the cold temperature testing.

Each vehicle entering the test program (once approved by the EPA WAM as described in Task 3) shall undergo an initial crankcase oil, oil filter and air filter replacement. Oil and air filters

shall be procured by the contractor per manufacturer's recommendations. Oil shall be drained and replaced with one of the EPA-supplied lubricants per the vehicle manufacturer's viscosity requirements. The lubricant level in the sump shall be allowed to stabilize and its level indicated on the dipstick shall be recorded. The vehicle shall then be driven 500 miles on market gasoline to condition the lubricant in preparation for the emissions test program. After the last test of each vehicle in the program the contractor shall measure and record the lubricant level indicated on the dipstick.

## **Task 6 Vehicle Testing**

### **6.1 Basic Testing Protocol**

The basic testing protocol is the testing of the recruited vehicles across all the test fuels over the California Unified Cycle (LA92) as a three phase, cold start test at FTP ambient and load conditions. All tests on a given vehicle must be done using the same 48-inch single roll (or equivalent) electric chassis dynamometer. More than one such dynamometer may be used in this program. The same driver shall also be used for all tests on a given vehicle (for all test repeats and across all test fuels). The contractor may comment on the feasibility of these requirements and propose additional measures that will reduce test to test variability, such as multi-shift testing on fewer chassis dynamometers.

#### **Option C**

The order in which the various test fuel and vehicle combinations are to be tested shall be randomized. However, replicate tests of a given fuel in a particular vehicle shall be done back-to-back. Specifically, the vehicle shall be tested twice (3 times if determined necessary per emissions variability criteria provided in Table 6.1-3 below) on a given fuel before moving on to the next test fuel in the matrix. This "back-to-back" testing eliminates the need to repeat additional vehicle preps (steps 1-6 of Table 6.1-1, below) between each replicate test on a given fuel. The contractor shall provide a separate cost estimate for employing this Option under Options A and B.

#### **Option D**

As a contrast to Option C, this Option requires the contractor to perform all exhaust emission tests on a given vehicle, even the replicates, in a random order. This will require more frequent vehicle preps between fuel changes but may result in a more preferable experimental design from a statistical point of view. The contractor shall provide a separate cost estimate for employing this Option under Options A and B.

The sequence of events for the testing of an individual vehicle is summarized in Tables 3a and 3b. Testing shall be conducted at 75°F for all vehicles and fuels in the test matrix, with additional cold temperature testing at 50°F for all non-FFV vehicles in the test fleet on a subset of 4 test fuels (fuels to be identified by the EPA WAM at a later date). Testing of FFVs shall take place at 75°F for all tests on all fuels. All vehicles shall be tested two or three times on each fuel at each test temperature (replicate tests). The need for a third test will be determined based on the variability of the previous two replicates (see step 14 in Table 6.1-1, below).

The emissions measured and reported are total hydrocarbons (THC), non-methane hydrocarbons (NMHC), non-methane organic gas (NMOG), oxides of nitrogen (NO<sub>x</sub>), nitrogen dioxide (NO<sub>2</sub>), carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), particulate matter (PM), speciated volatile organic compounds (speciated VOCs), nitrous oxide (N<sub>2</sub>O), ammonia (NH<sub>3</sub>) and hydrogen cyanide (HCN), metals, ions, semi-volatile organic compounds (SVOC) as well as PM characterization by QCM, EEPs and EC/OC. The contractor shall comment on the feasibility and cost of incorporating bag (phase) level measurement of ethanol emissions (such as analysis by INNOVA photoacoustic analyzer).

The following exhaust emission measurements will be made:

1. Bag (phase) level and composite THC, NMHC, NMOG, CO, CO<sub>2</sub>, NO<sub>x</sub>, NO<sub>2</sub>, ethanol and PM emissions
2. Bag (phase) level speciated VOCs for a subset of tests (See Task 6.2, below). The list of compounds to be measured and analyzed is given in Appendix D
3. EC/OC PM integrated over the whole test cycle for a subset of tests (See Task 6.3, below)
4. Continuous PM by QCM and equilibrated PM by bag (phase) for a subset of tests (See Task 6.4, below)
5. Continuous particulate size and number by EEPs for a subset of tests (See Task 6.4, below)
6. SVOCs integrated over the whole test cycle for a subset of tests (See Task 6.5, below). The list of compounds to be measured and analyzed is provided in Appendix E
7. Metals integrated over the whole test cycle for a subset of tests (See Task 6.6, below). The list of metals to be measured and analyzed is provided in Appendix F
8. Sulfate, chloride and nitrate ions integrated over the whole test cycle for a subset of tests (See Task 6.7, below).
9. Continuous and integrated by bag (phase) emissions of the following species measured in raw exhaust for a subset of tests (see Task 6.8, below): THC, NMHC, CO, CO<sub>2</sub>, NO<sub>x</sub>, N<sub>2</sub>O, NH<sub>3</sub> and HCN.

The contractor shall acquire all available data from the vehicle's onboard diagnostic (OBD) system during all emissions tests using contractor-supplied data acquisition equipment. The contractor shall comment on the feasibility of this requirement and the capability of the available data acquisition equipment to meet this requirement.

The facilities for testing shall meet the requirements of 40 CFR Part 86 Subpart B and 40 CFR Part 86 Subpart C as they apply to vehicle exhaust testing. THC, NMHC, NMOG, NO<sub>x</sub>, NO<sub>2</sub>, CO, and CO<sub>2</sub>, and PM emissions sampling and measurement shall be conducted as specified in 40 CFR 1065. The minimum detection limit for NO<sub>2</sub> measurements shall be 0.5 ppb. If some aspect of testing will need to be done in variance to the above specifications the contractor shall describe why that is the case and how it may impact the test results. Variances must be approved the EPA WAM before testing may begin. The methodology to be used for determining NMHC and NMOG emissions from vehicles tested on ethanol-containing fuels is described in the CARB document “California Non-Methane Organic Gas Test Procedures<sup>1</sup>”

The contractor shall recommend sample collection and analytical methods for non-standard emission measurements. These recommendations will take into account analytical detection limits, emission rates expected of Tier 2 vehicles and the requirement to collect all samples in the course of a single LA92 test. All sample collection and analytical methods related to non-standard emission measurements must be approved by the EPA WAM.

### 6.1.1 Fuel Change and Test Execution Sequence

#### Option C

Under this Option the contractor shall follow the fuel change and test execution sequence as described in Table 6.1-1, below. The first two emission tests on a given vehicle and fuel combination shall be performed back-to-back. The second replicate shall be run in the same way as the first except that only THC, NMHC, NMOG, CO, CO<sub>2</sub>, NO<sub>x</sub>, NO<sub>2</sub>, ethanol and PM emissions shall be measured. If the difference between any of the criteria pollutant measurements is greater than the variability criteria listed in Table 6.1-3, a third replicate shall be run in the same way as the second.

**Table 6.1-1. Fuel Change and Test Execution Sequence for Option C**

Step	Description
1	Drain vehicle fuel completely via fuel rail whenever possible
2	Turn vehicle ignition to RUN position for 30 seconds to allow controls to allow fuel level reading to stabilize. Confirm the return of fuel gauge reading to zero
3	Fill fuel tank to 40% with next test fuel in sequence. Fill-up fuel must be at the temperature of the next LA92 test (75 or 50°F)
4	Start vehicle and execute catalyst sulfur removal procedure described in Appendix C of CRC E-60 Program report
5	Drain fuel and refill to 40% with test fuel. Fill-up fuel must be at the temperature of the next LA92 test (75 or 50°F)
6	Start vehicle and drive one LA4 cycle. Allow vehicle to idle in park for 2 minutes before engine shut-down

7	Move vehicle to soak area without starting or driving
8	Park vehicle in soak area at proper temperature (75 or 50°F) for 12-36 hours
9	Move vehicle to test area without starting engine
10	Perform LA92 cycle emissions test
11	Park vehicle in soak area of proper temperature for 12-36 hours
12	Move vehicle to test area without driving
13	Perform LA92 emissions test
14	Determine whether third replicate is necessary, based on data variability criteria (see Table 6.1-3 below)
15	If a third replicate is required, repeat steps 10, 11 and 12
16	If third replicate is not required, return to step 1 and proceed with next fuel in test sequence

#### Option D

Under this Option all emissions tests, including replicate tests shall be fully randomized. All replicates on a given fuel shall be run in the same way as the first emissions test except that only THC, NMHC, NMOG, CO, CO<sub>2</sub>, NO<sub>x</sub>, NO<sub>2</sub>, ethanol (by INNOVA or similar analyzer, if available) and PM emissions shall be measured. If the first two emission tests performed on a given fuel do not meet the variability criteria listed in Table 6.1-3, a third replicate shall be run in the same way as the second.

**Table 6.1-2. Fuel Change and Test Execution Sequence for Option D**

Step	Description
1	Drain vehicle fuel completely via fuel rail whenever possible
2	Turn vehicle ignition to RUN position for 30 seconds to allow fuel level reading to stabilize. Confirm the return of fuel gauge reading to zero
3	Fill fuel tank to 40% with next test fuel in sequence. Fill-up fuel must be at the temperature of the next LA92 test (75 or 50°F)
4	Start vehicle and execute catalyst sulfur removal procedure described in Appendix C of CRC E-60 Program report
5	Drain fuel, and refill to approximately 40% with test fuel. Fill-up fuel must be at the temperature of the next LA92 test (75 or 50°F)
6	Start vehicle and drive one LA4 cycle. Allow vehicle to idle in park for 2 minutes before engine shut-down
7	Move vehicle to soak area without starting or driving

8	Park vehicle in soak area at proper temperature (75 or 50°F) for 12-36 hours
9	Move vehicle to test area without starting engine
10	Perform LA92 emissions test
11	Return to step 2 to prepare for next fuel under the fully randomized test schedule

Each vehicle shall be tested at least twice on a given fuel regardless of option selection. After two tests have been completed and the acquired data has passed all quality control verifications as described in the contractor's QAPP, the need for a third test shall be determined by following the variability criteria shown in Table 6.1-3:

**Table 6.1-3. Variability Criteria for Triplicate Testing**

<b>Gaseous Emission</b>	<b>Criteria for requiring a third test (composite cycle emissions)</b>
CO <sub>2</sub>	Ratio of higher / lower > (TBD)
CO	Ratio of higher / lower > (TBD)
NO <sub>x</sub>	Ratio of higher / lower > (TBD)
NMHC	Ratio of higher / lower > (TBD)

If the ratio of any of the above pollutants on a pair of tests on a given vehicle and fuel combination exceeds the levels shown in Table 6.1-3, the contractor shall proceed with the third test and promptly notify the EPA WAM, making available the electronic summary reports of the tests in question.

## 6.2 Speciation of Volatile Organic Compounds (VOCs)

VOC speciation shall include C1-C12 hydrocarbons as well as light alcohols, aldehydes, and ketones. Sampling and analysis of C2-C12 hydrocarbons will be done using CARB method 1002/1003, "Procedure for the Determination of C2-C12 Hydrocarbons in Automotive Exhaust Samples by Gas Chromatography". Sampling and analysis of carbonyl compounds will be done using CARB method 1004, "Determination of Aldehyde and Ketone compounds in Automotive Source Samples by High Performance Liquid Chromatography". Analysis of C1 – C4 HC samples shall be done within one hour of completion of the emissions test. Subsequent analysis of the additional compounds of interest shall be done within 4 hours of emission test completion. The time between sample collection and the start of C1-C4 HC analysis shall be reported. The VOCs to be analyzed are identified in Appendix D. The contractor shall comment on the feasibility of these requirements and propose additional measures to improve precision of VOC speciation. All methods used in the measurement of VOCs must be approved by EPA WAM.

### **Option A (continued from Task 4)**

This Option requires that VOC speciation be performed for all 3 phases on all fuels for a subset of 3 vehicles (vehicles to be selected by the EPA WAM). The remaining 16

vehicles shall only require VOC speciation of phase 1 of the LA92 test (for all test fuels). This shall be performed for tests at 75°F only, and for only one test on each fuel (no repeat speciations are required).

**Option B (continued from Task 4)**

Under Option B, VOC speciation shall be performed for all 3 phases of the first LA92 test on each vehicle and fuel combination at 75°F only. No repeat speciations are required.

### **6.3 Elemental and Organic Carbon (EC/OC)**

The contractor shall measure EC and OC integrated over the whole test cycle using a semi-continuous EC/OC analyzer, A second analyzer, sampling through a Teflon filter in parallel with the first analyzer, shall be used to quantify sampling artifact.

**Option A (continued from Task 4)**

EC/OC shall be measured on 2 fuels (one E0 and one E10) and 6 vehicles (vehicles to be selected by EPA WAM) at 75°F only. No EC/OC measurements are required in repeat LA92 tests.

**Option B (continued from Task 4)**

EC/OC shall be measured on 6 fuels (two E0, two E10, and two E85 fuels) and 12 vehicles (vehicles to be selected by EPA WAM) at 75°F only. No EC/OC measurements are required in repeat LA92 tests.

### **6.4 Continuous Particulate Matter**

#### **6.4.1 Continuous PM mass**

Continuous PM mass shall be measured with a Quartz Crystal Microbalance (QCM) and equilibrated by bag (phase). Alternate analysis methods may be proposed by the contractor for consideration by the EPA WAM.

#### **6.4.2 Continuous PM Particle Size and Number**

Continuous particle size and number shall be measured with an Engine Exhaust Particle Sizer (EEPS, TSI Inc.). The contractor shall include in the work plan a detailed description of any proposed dilution scheme associated with EEPS measurement. Alternate analysis methods may be proposed by the contractor for consideration by the EPA WAM.

**Option A (continued from Task 4)**

Continuous PM mass by QCM and size distribution by EEPS shall be measured on 2 fuels (one E0 and one E10) and 6 vehicles (vehicles to be selected by EPA WAM) at 75°F only. No QCM or EEPS measurements are required in repeat LA92 tests.



**Option B (continued from Task 4)**

Continuous PM mass by QCM and size distribution by EEPS shall be measured on 6 fuels (two E0, two E10, and two E85 fuels) and 12 vehicles (to be selected by EPA WAM) at 75°F only. No QCM or EEPS measurements are required in repeat LA92 tests.

**6.5 Speciation of Semi-Volatile Organic Compounds (SVOCs)**

SVOC emissions shall be integrated over the whole test cycle. The list of substances which must be quantified is provided in Appendix E. (EPA will define SVOC sampling system requirements in a future amendment to this Performance Work Statement).

The contractor shall comment on the feasibility of these requirements and propose additional measures to improve the precision of SVOC speciation. All sampling and analytical methods used in the measurement of SVOCs must be approved by EPA WAM.

**Option A (continued from Task 4)**

SVOC speciation shall be performed on 2 fuels (one E0 and one E10) and 6 vehicles (vehicles to be selected by EPA WAM) at 75°F only. SVOC speciation is not required in repeat LA92 tests.

**Option B (continued from Task 4)**

SVOC speciation shall be performed on 6 fuels (two E0, two E10, and two E85 fuels) and 12 vehicles (vehicles to be selected by EPA WAM) at 75°F only. SVOC speciation is not required in repeat LA92 tests.

Note: The same supplemental primary dilution tunnel may be used to measure SVOC, metal and ion emissions

**6.6 PM Metals**

Emissions of selected metals shall be integrated over the whole test cycle. The list of metals which must be quantified is provided in Appendix F. (EPA will define PM metal sampling system requirements in a future amendment to this Performance Work Statement).

The contractor shall comment on the feasibility of these requirements and propose additional measures to improve the precision of metal emission measurements. All sampling and analytical methods used in the measurement of metal emissions must be approved by EPA WAM.

**Option A (continued from Task 4)**

The measurement of metal emissions shall be performed on 2 fuels (one E0 and one E10) and 6 vehicles (vehicles to be selected by EPA WAM) at 75°F only. Metal emissions need not be measured in repeat LA92 tests.

**Option B (continued from Task 4)**

The measurement of metal emissions shall be performed on 6 fuels (two E0, two E10, and two E85 fuels) and 12 vehicles (vehicles to be selected by EPA WAM) at 75°F only.

Metal emissions need not be measured in repeat LA92 tests.

Note: The same supplemental primary dilution tunnel may be used to measure SVOC, metal and ion emissions

## **6.7 Ions**

Emissions of sulfate, chloride and nitrate ions shall be integrated over the whole test cycle. The contractor shall comment on the feasibility of these requirements and propose additional measures to improve the precision of ion emission measurements. All sampling and analytical methods used in the measurement of ion emissions must be approved by EPA WAM.

### **Option A (continued from Task 4)**

The measurement of ion emissions shall be performed on 2 fuels (one E0 and one E10) and 6 vehicles (vehicles to be selected by EPA WAM) at 75°F only. Ion emissions need not be measured in repeat LA92 tests.

### **Option B (continued from Task 4)**

The measurement of ion emissions shall be performed on 6 fuels (two E0, two E10, and two E85 fuels) and 12 vehicles (vehicles to be selected by EPA WAM) at 75°F only. Ion emissions need not be measured in repeat LA92 tests.

Note: The same supplemental primary dilution tunnel may be used to measure SVOC, metal and ion emissions

## **6.8 Continuous Measurements of Gaseous Emissions in Raw Exhaust**

### **6.8.1 Continuous THC, NMHC, CO, CO<sub>2</sub> and NO<sub>x</sub>**

Continuous and integrated by bag (phase) emissions of THC, NMHC, CO, CO<sub>2</sub> and NO<sub>x</sub> shall be measured in raw exhaust for all tests, regardless of option selection. The continuous measurements shall be made at a minimum sampling frequency of 1 Hz. A direct raw exhaust flow measurement device, such as SEMTECH EFM made by Sensors Inc. (or equivalent), shall be used. The contractor shall comment on the availability of test cells with this capability and propose methods for continuous raw emissions data alignment. The contractor shall provide sample test data illustrating the agreement between the CVS and raw exhaust measurements of THC, CO, NO<sub>x</sub> and CO<sub>2</sub> achievable in their laboratory using Tier 2 vehicles, including an assessment of measurement uncertainty for each method.

### **6.8.2 Continuous N<sub>2</sub>O, NH<sub>3</sub> and HCN**

Continuous and integrated by bag (phase) emissions of N<sub>2</sub>O, NH<sub>3</sub> and HCN shall be measured using Fourier Transform Infrared Spectroscopy (FTIR) or an alternate method proposed by the contractor and approved by the EPA WAM

**Option A (continued from Task 4)**

The measurements of N<sub>2</sub>O, NH<sub>3</sub> and HCN emissions shall be done on 6 vehicles (vehicles to be selected by the EPA WAM) at 75°F on E0 and E10 only (no repeat tests).

**Option B (continued from Task 4)**

The measurements of N<sub>2</sub>O, NH<sub>3</sub> and HCN emissions shall be done on 12 vehicles (vehicles to be selected by the EPA WAM) at 75°F on E0, E10, and E85 fuels (no repeat tests).

Note: The same 2 or 6 fuels and 6 or 12 vehicles will be used in EC/OC, QCM, EEPs, SVOC, metal, ion and raw exhaust measurements for Options A and B in Tasks 6.3 – 6.8.

**Task 7 Deliverables****7.1 Weekly Reports**

The contractor shall provide 30-60 minute telephone conference reports weekly that summarize progress to date. Weekly test results in spreadsheet form shall be provided to the EPA WAM.

The oral report shall indicate progress achieved in the preceding week, technical issues encountered, solutions to issues (proposed or attempted), and projected activity in the following week. This report shall include any potential issues or circumstances that arise causing any delays in the testing. The WAM or his/her designated alternate shall participate in these phone conferences.

**7.2 Monthly Written Progress Reports**

The contractor shall provide monthly progress reports with invoices. The reports shall track percentages of hours used in each task and whether the project is on schedule. The contractor shall explain problems encountered including resolutions and indicate if the schedule or budget was compromised.

The reports shall summarize the progress made during the reporting month, technical issues encountered, solutions to issues (proposed or attempted), and projected activity in the following month. Graphical presentations shall be made to display results if data has been collected.

**7.3 Data Files**

The contractor shall submit the data to EPA in three formats, each format having different levels of post processing and aggregation. The files are nominally:

1. Non-Post processed data files (raw data): These are the native test level data files, usually generated by instrumentation, that have not been post-processed for such purposes as time-series alignment or calculation of continuous emission rates. They shall

be submitted to EPA as a deliverable for this work assignment and labeled using the following convention:

‘e’<VehID>\_<fuelID>\_raw.<extension>

where *VehID* is the unique identifier designated for vehicle, *fuelID* is the unique identifier assigned to each fuel type, and *extension* is the appropriate file extension for the file’s data format. Modifications to the specified file-naming convention may be adopted following approval from the EPA Work Assignment Manager.

2. Post processed data files: These are the minimally processed test level data files that will contain the composite, test level, bag level, and 1 Hertz (modal) emission rates in the units specified in 40 CFR Part 86. They shall be submitted to EPA as a deliverable for this work assignment and labeled using the following convention:

‘e’<VehID>\_<fuelID>\_pst.<extension>

where *VehID* is the unique identifier designated for vehicle, *fuelID* is the unique identifier assigned to each fuel type, and *extension* is the appropriate file extension for the file’s data format. Modifications to the specified file-naming convention may be adopted following approval from the EPA WAM.

3. The contractor shall also deliver Mobile Source Observation Database (MSOD) input data files containing test results and vehicle information using table names, structures, field names and field formats as specified in Appendix C. During the program it may be necessary to design and apply new data types, tables and structures. As necessary, such modifications to the data structure may be proposed by the contractor and approved by the EPA WAM. The contractor shall inform the EPA WAM if they believe the specified precision for a given field(s) is inadequate or inappropriate. The WAM and the contractor shall then determine what changes in the format may be necessary to accurately store the data for future use in MSOD.

The contractor shall include in the work plan prototype electronic versions of the above three file types for the inspection and approval of the EPA WAM.

#### **7.4 Mode of Delivery**

The contractor shall deliver one set of files to the EPA WAM at the USEPA National Vehicle and Fuel Emissions Laboratory at Ann Arbor, Michigan.

The contractor shall deliver the data contained in the MSOD formatted tables via a secure method to be proposed by the contractor and approved by the WAM. Under no circumstances shall the contractor deliver these files by insecure methods such as electronic mail attachments or First Class Mail.

#### **7.5 Draft Final Report**

The contractor shall develop a draft final report that details the work completed including any issues encountered and results from Tasks 1 through 7.

The draft report shall be submitted to EPA that includes:

- 1) Recruitment procedures
- 2) Vehicle-related information, VIN, mileage, emission system descriptions, etc.
- 3) Measurement methodologies and quality measures
- 4) Test completion diary for individual vehicles detailing any relevant information regarding completion of each test
- 5) All data collected in Tasks 1 through 7 of this work assignment. Graphical displays summarizing the data by fuel type and other relevant breakdowns

The draft final report shall be delivered to EPA within six weeks of the testing completion.

## 7.6 Final Report

The contractor shall provide a final report incorporating EPA comments, within 30 days of receiving comments from EPA. The report shall be in hard copy plus an agreed-upon electronic format. Microsoft Word or Adobe portable document files (\*.pdf) are acceptable formats.

### Schedule of Deliverables

Steps	Duration	Completion Date
Conference call to address outstanding issues	As required	October 2, 2007
Project work plan submission	2 weeks	October 5, 2007
<i>EPA reviews and approves work plan</i>	<i>1 week</i>	October 12, 2007
Draft QAPP	6 weeks	November 21, 2007
<i>EPA reviews and approves draft QAPP</i>	<i>3 weeks</i>	December 12, 2007
Vehicle Recruitment	as required for test schedule sequence	
<i>Vehicles accepted by EPA shall begin testing on a rolling basis</i>		
Fuel Acquisition	as required for test schedule sequence	
150 vehicle tests completed, end of current work assignment		May 18, 2008
Emissions Testing	70 weeks	July 5, 2009
Data Delivery	Ongoing as tests completed (incl. replicates)	
3 versions of formatted data for each veh/fuel ID	5 working days	

Draft Report  
Final Report

6 weeks  
4 weeks after EPA  
comments

August 15, 2009  
October 11, 2009

Work Assignment Manager (WAM)

Constance Hart, 734/ 214-4340

Alternate WAM

Carl Scarbro, ASD 734/214-4209

Technical Contacts

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<sup>4</sup> "California Non-Methane Organic Gas Test Procedures". Amended version, July 30, 2002. Available online at the California Air Resources Board website: [http://www.arb.ca.gov/msprog/levprog/cleandoc/clean\\_nmogtps\\_final.pdf](http://www.arb.ca.gov/msprog/levprog/cleandoc/clean_nmogtps_final.pdf).

**APPENDIX B**

**COST DETAIL FOR WORK ASSIGNMENT 0-01**

# SOUTHWEST RESEARCH INSTITUTE®

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Refer to: 03-50782

October 25, 2007

Via E-mail: [Boris.David@epamail.epa.gov](mailto:Boris.David@epamail.epa.gov)

U. S. EPA  
Office of Transportation Air Quality  
2000 Traverwood  
Ann Arbor, MI 48105-2195

Attn: David Boris

Subject: EPA Contract No. EP-C-07-028  
Work Assignment No. 0-1  
SwRI Proposal No. 03-50782

Dear Mr. Boris:

Enclosed please find SwRI's subject cost proposal. Please note that the cost for leasing the vehicles is based upon a two year lease. It was difficult to get the lease companies to agree to a lease shorter than three years. Two years was as short of a term to which they would agree.

Should you have any questions regarding the cost proposal, please feel free to contact me at 210-522-3948 or email at [sheryl.twilligear@swri.org](mailto:sheryl.twilligear@swri.org).

Sincerely,



Ms. Sherry Twilligear  
Senior Contract Specialist

SAT/jb

Cc: K. Whitney, SwRI (via email T. Davison)  
P. Merritt, SwRI (via email T. Davison)



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